Arkansas Water Resources Center

AWRC

April 6 and 7

1993 RESEARCH CONFERENCE

FOCUS on PHOSPHORUS

▼ Workshop By Andrew Sharpley
Phosphorus Management for Agriculture and Water Quality

▼ Presentation and Panel Discussion
on Phosphorus Issues in Arkansas

▼ Demonstration of Geographic Information Systems
in Water Resources Studies

PLAINTIFF'S EXHIBIT
CM 38

ONRC 00583

EXHIBIT
129

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ARKANSAS WATER RESOURCES CENTER 1993 RESEARCH CONFERENCE

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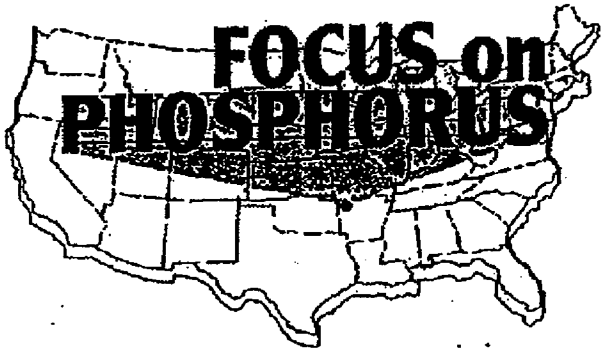
Arkansas Water Resources Center

April 6 and 7

1993 RESEARCH CONFERENCE



SCHEDULE OF ACTIVITIES

<u>April 6</u>

1:30 pm — **Welcome - Kenneth F. Steele, Director**
Arkansas Water Resources Center

1:35 pm — **Workshop "*Phosphorus Management for Agriculture and Water Quality*" by Andrew Sharpley, USDA-Agricultural Research Service, National Agricultural Water Quality Laboratory, Durant, OK**

6:00 pm — **Evening reception**

<u>April 7</u>

8:00 to 8:30 am — **Registration**

8:30 am — **Introduction - Kenneth F. Steele, Director**
Arkansas Water Resources Center

8:35 am — **Presentations on Arkansas studies involving phosphorus:**
Moderator: David Parker, Associate Director Arkansas Water Resources Center and Professor of Civil Engineering

Soil Fertility Phosphorus Status of Arkansas Soils
Wayne E. Sabbe, Department of Agronomy
University of Arkansas, Fayetteville

Immobilization of Phosphorus in Poultry Litter With Aluminum, Calcium, and Iron Amendments
Philip Moore, USDA Agricultural Research Services
University of Arkansas, Fayetteville

Transport of Phosphorus from Land Areas Treated with Animal Manures
Dwayne R. Edwards
Department of Biological and Agricultural Engineering
University of Arkansas, Fayetteville

Presentations on Arkansas studies involving phosphorus continued:

Spatial Relationships Between Phosphorus and Aqueous Phosphorus Concentrations in the War Eagle Watershed
H. Don Scott, Department of Agronomy
University of Arkansas, Fayetteville

Phosphorus Dynamics in Streams and Reservoirs of the Western Ozark Plateau
Richard L. Meyer, Department of Biological Sciences
University of Arkansas, Fayetteville

Minimizing Surface Water Eutrophication by Phosphorus Management
Tommy Daniel, Department of Agronomy
University of Arkansas, Fayetteville

Panel Discussion: *Phosphorus Issues/Problems/Solutions*
Moderator: John T. Gilmour, Department of Agronomy Chairperson

Allen Carter
Arkansas Game & Fish Commission
Little Rock, Arkansas

John Giese
Arkansas Department of Pollution Control & Ecology
Little Rock, Arkansas

Tom McKinney
Representative of the Ozark Headwaters Group of the Sierra Club
West Fork, Arkansas

Ronnie Murphy
U.S. Soil Conservation Service
Little Rock, Arkansas

Andrew Sharpley
USDA-Agricultural Research Service,
National Agricultural Water Quality Laboratory
Durant, Oklahoma

Earl Smith
Arkansas Soil & Water Conservation Commission
Little Rock, Arkansas

12:30 pm to 1:30 pm- Luncheon in Atrium, with awards given for outstanding contributions to Arkansas Water Resources.

2:00 pm to 4:00 pm- Demonstration of the use of Geographic Information Systems (GIS) in water resource studies.

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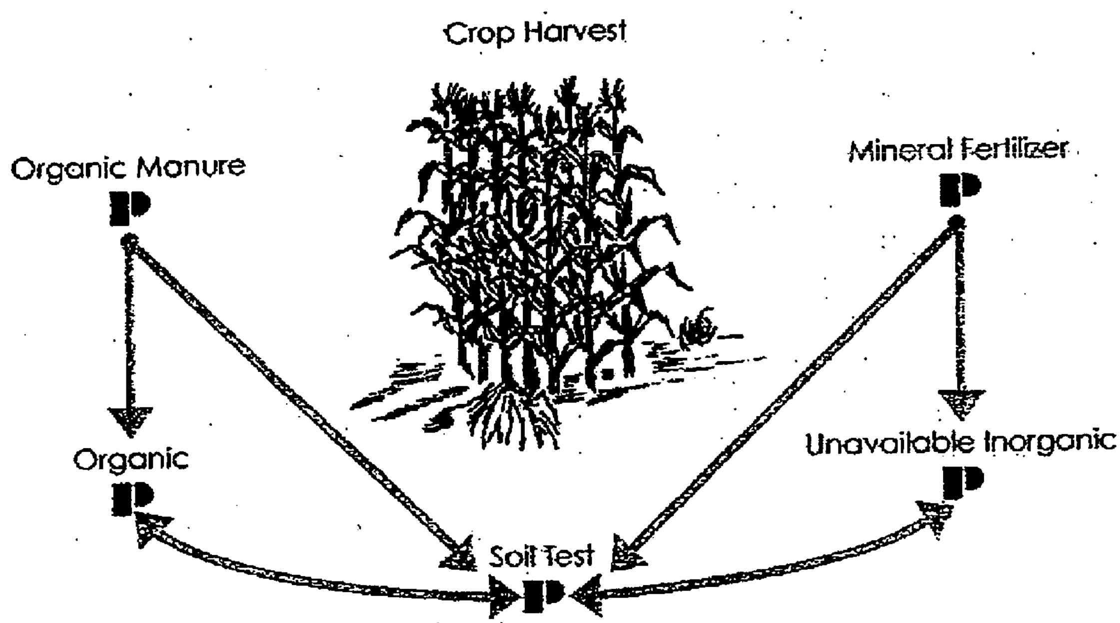
Phosphorus Management for Agriculture, Water Quality



Workshop by
Andrew Sharpley
USDA-ARS, National Agricultural Water Quality Laboratory

ONRC 00587

PHOSPHORUS MANAGEMENT FOR AGRICULTURE AND WATER QUALITY

Andrew Sharpley
USDA-ARS, National Agricultural Water Quality Laboratory,
P.O. Box 1430, Durant, Oklahoma

Eutrophication of surface waters can be accelerated by an increased input of nutrients, which limits water use for fisheries, recreation, industry, or drinking. Although nitrogen (N) and carbon (C) are associated with eutrophication, most attention has focused on phosphorus (P) inputs, because of the difficulty in controlling the exchange of N and C between the atmosphere and water, and fixation of atmospheric N by some blue-green algae. Thus, P often limits eutrophication and its control is of prime importance in decreasing accelerated eutrophication.

Extensive surveys and research has shown that the trophic state or biological productivity of lakes increases with the P content of lake water (Fig. 1). In Figure 1, lake productivity is quantified by chlorophyll content. However, dynamic lake properties and site variability mean that these are guidelines only. In terms of general lake use, oligotrophic lakes create no problems, mesotrophic lakes create some problems, and eutrophic and hypereutrophic lakes pose many problems for most users. In-lake P concentrations between 10 and 20 ppb are considered critical values above which eutrophication is accelerated. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (200 to 300 ppb). The disparity between critical soil and lake water P concentrations, in terms of bioproductivity, emphasizes the sensitivity of ecosystems to potential inputs of P from agriculture.

Due to the easier identification and control of point sources of P and a lack of direct human health risks associated with eutrophication, less attention has been given

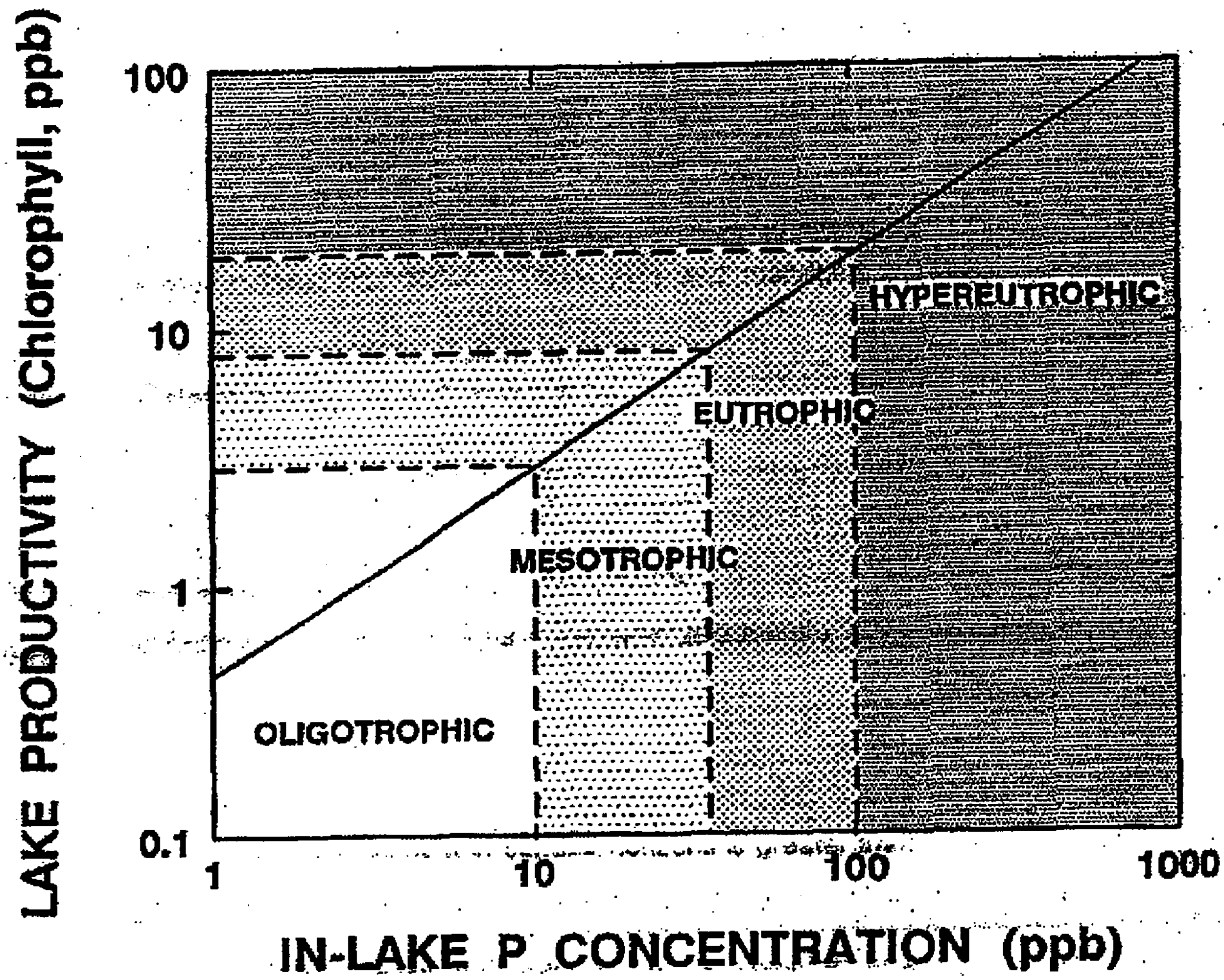


Figure 1. Lake productivity, as chlorophyll content, increases with P concentration of lake water.

to management strategies minimizing nonpoint transport of P from agricultural land. However, the negative impacts of P must be balanced with the benefits of P use. Profitable crop production depends on a sound P-management program as well as several other factors; and judicious fertilizer use can reduce erosion and runoff potential by increased vegetative cover. Clearly, P management is of agronomic and environmental importance. Thus, soils and management practices that are vulnerable to P loss, must be identified to implement effective and economically viable management systems that minimize P transport.

Before we can develop sustainable management systems for P, we need to understand what forms of P occur in soil, their plant availability, and the processes controlling soil P removal and transport in runoff. Using this information, we can assess how to manage agricultural P to maximize soil productivity, while minimizing P transport and identify fields vulnerable to P loss in runoff.

Forms in Soil

Soil P exists in inorganic and organic forms (Fig. 2). In most soils, the P content of surface horizons is greater than subsoil due to the sorption of added P and greater biological activity and accumulation of organic material in surface layers. Soil P content varies with parent material, texture, and management factors, such as rate and type of P applied and soil cultivation. These factors also influence the relative amounts of inorganic and organic P. In most soils, 50 to 75% of the P is inorganic, although this fraction can vary from 10 to 90%.

For simplicity we have assumed soil test P is the primary source of P for plant uptake, although we know solution P is actually taken up by plants (Fig. 2). Adsorption and desorption of P occur between soil test P and unavailable forms (fixed, occluded, or stable P), as a function of soil properties such as iron, aluminum, and calcium content.

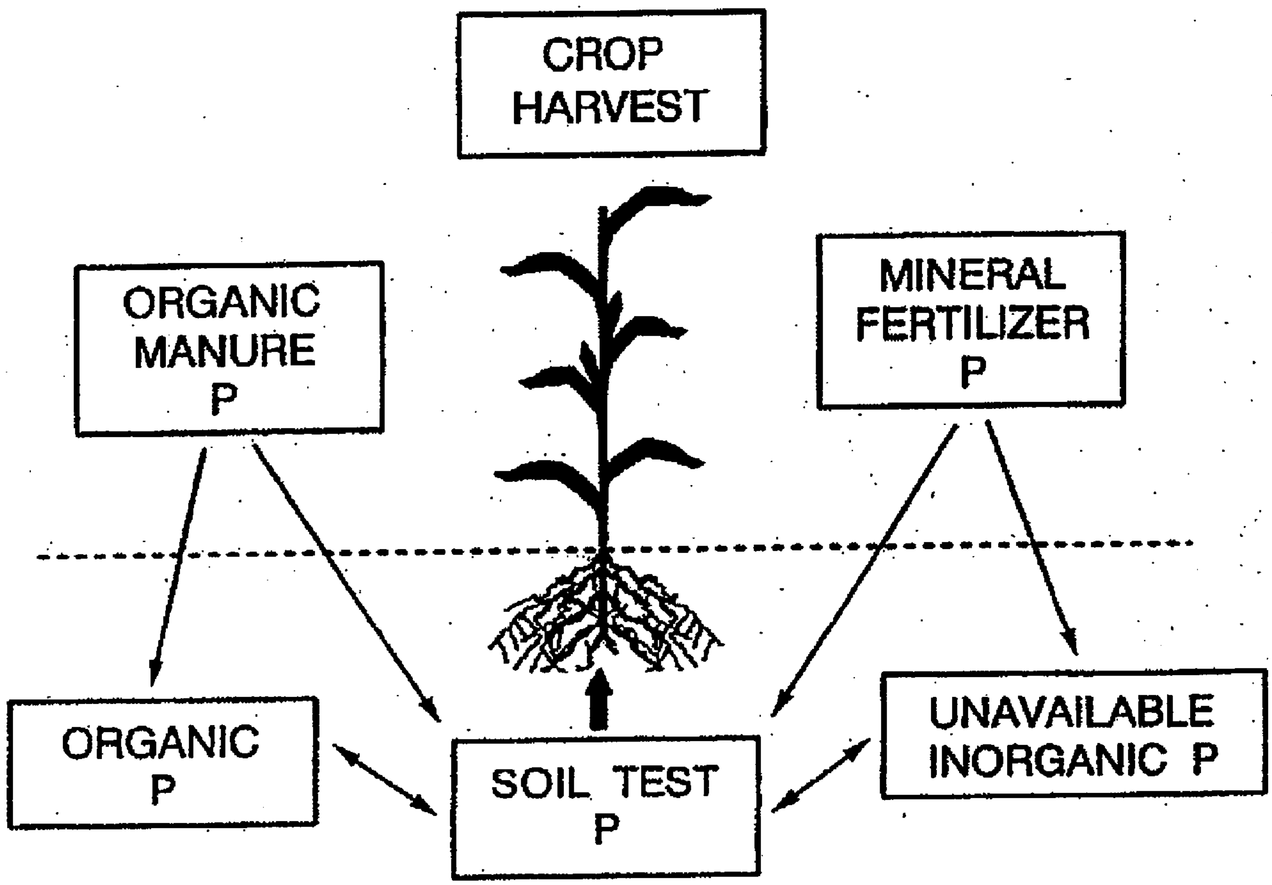


Figure 2. The soil phosphorus cycle.

Adsorption of P by soil occurs rapidly and because of the high binding energy between soil and P, adsorption tends to dominate desorption. Thus, a general decrease in soil P availability occurs after P is applied (Fig. 3). If soil test P decreases below a critical level, desorption of unavailable P can occur, but usually at a rate too slow to satisfy crop P requirements. The critical soil test P level of a given soil is determined by the content and activity of iron, aluminum, and calcium compounds adsorbing P.

Mineralization of organic P and immobilization of P by transformation of inorganic to organic P, make organic P a variable but important form in overall soil P fertility. Continual soil cultivation generally decreases soil organic P content and overall inherent soil fertility. In some cases, mineralization of organic P can supply sufficient P for crop growth. Thus, soil P tests should give credit for organic P mineralization in these soils to minimize the potential for over P fertilization.

Transport in Runoff

The loss of P in runoff occurs in dissolved and sediment-bound forms. Dissolved P is comprised mostly of orthophosphate which is immediately available for algal uptake. Sediment P includes P sorbed by soil and organic material eroded during runoff and can provide a variable (10 to 90% of total P) but long-term source of P to aquatic biota. Runoff from grass or forest land carries little sediment and is dominated by dissolved P, whereas sediment P is the major form of P transported from conventionally tilled land (75 to 95%). As a result, erosion control is of prime importance in minimizing P loss from agricultural land.

The main factors controlling P loss in runoff are conceptualized in Figure 4. The first step in the movement of P in runoff is the desorption, dissolution, and extraction of P from a thin layer (0.04 to 0.12 inch) of surface soil and plant material (Fig. 4). The remaining runoff percolates through the soil profile where sorption by P-deficient subsoils results in

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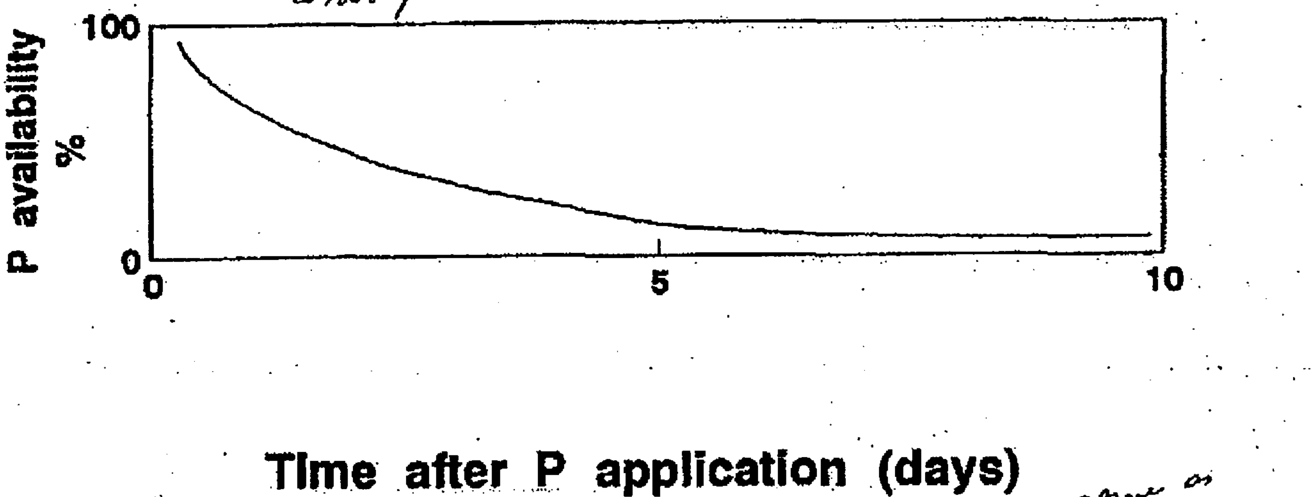
incorporated



plant residues same as a source of dissolved P

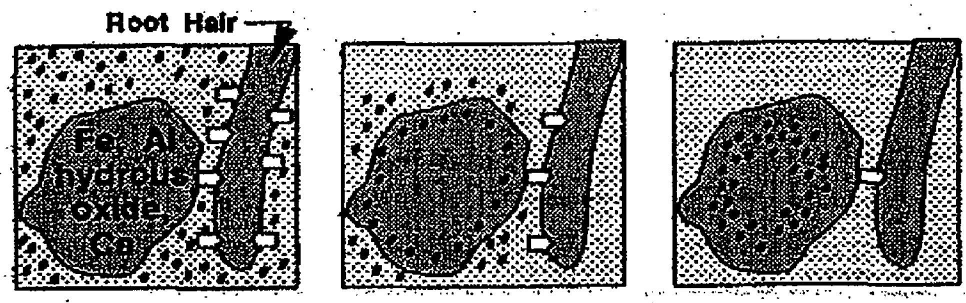


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Figure 3. Plant availability of phosphorus decreases with time after application.

El Reno no till research

top 2cm is actual zone soil tests to 6" may dilute the numbers

P mobility

adsorption

mobility ↑ as sat's go

P adsorption

clay loam sand texture

? textures

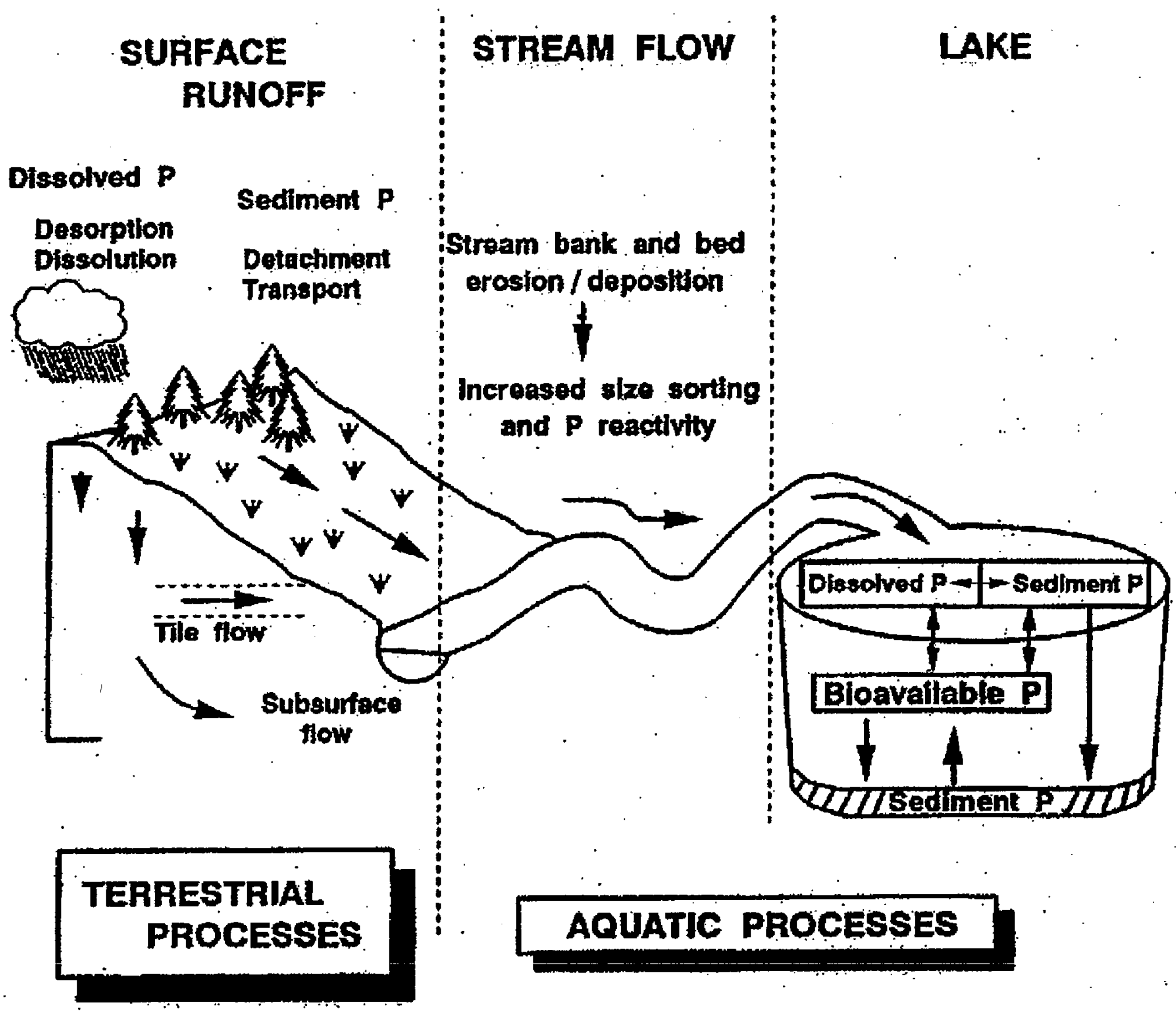

Figure 4. Processes involved in the transport of P from terrestrial to aquatic ecosystems.

low dissolved P concentrations in subsurface flow. Exceptions may occur in organic, permeable coarse-textured, and reduced waterlogged soils, with low P-sorption capacities.

As P is tightly sorbed by soil material, erosion determines sediment P movement (Fig. 4). Sources of sediment P in streams include eroding surface soil, plant material, stream banks, and channel beds. Where there is a permanent vegetative cover, such as forest or pasture, the primary source of sediment is from stream bank erosion. This sediment will have characteristics similar to the subsoil material of the area, which is often of low P content. During detachment and movement of sediment in runoff and stream flow, the finer-sized fractions of source material are preferentially eroded and the coarser material can be deposited. Thus, the P content and reactivity of eroded particulate material is usually greater than source soil. This also means that P becomes more algal available as it moves from the edge of a field to lake.

Clearly, soil P content, runoff, and erosion are the major factors determining P loss in runoff. As the soil test P content of soils susceptible to runoff or erosion increases, the potential for P loss in runoff increases.

As a result of these complex and interactive processes affecting P transport in runoff, there is a general increase in P loss with increasing cultivation and land disturbance. An EPA sponsored survey of 928 nonpoint source type watersheds in the U.S., shows P movement increased as the proportion of land as forest decreased and as agriculture increased (Fig. 5). On an area basis, cultivated and improved pasture contributes approximately 3 million tons of P annually to surface waters; almost 70% of the total P load.

Generally, the loss of P in runoff is less than 0.5 lbs acre^{-1} (Fig. 5) and, thus, not of agronomic nor economic concern to a farmer. However, these losses maintain dissolved P concentrations greater than critical levels associated with accelerated eutrophication (10 to 20 ppb). Consequently, these losses can be of environmental concern to receiving lakes.

Major land use	Dissolved P (ppb)
90% Forest	9
75% Forest	12
50% Forest	14
Mixed	21
50% Range (remainder forest)	18
75% Range	37
50% Range (remainder agric.)	25
50% Agric.	37
90% Agric.	71
40% Urban	43

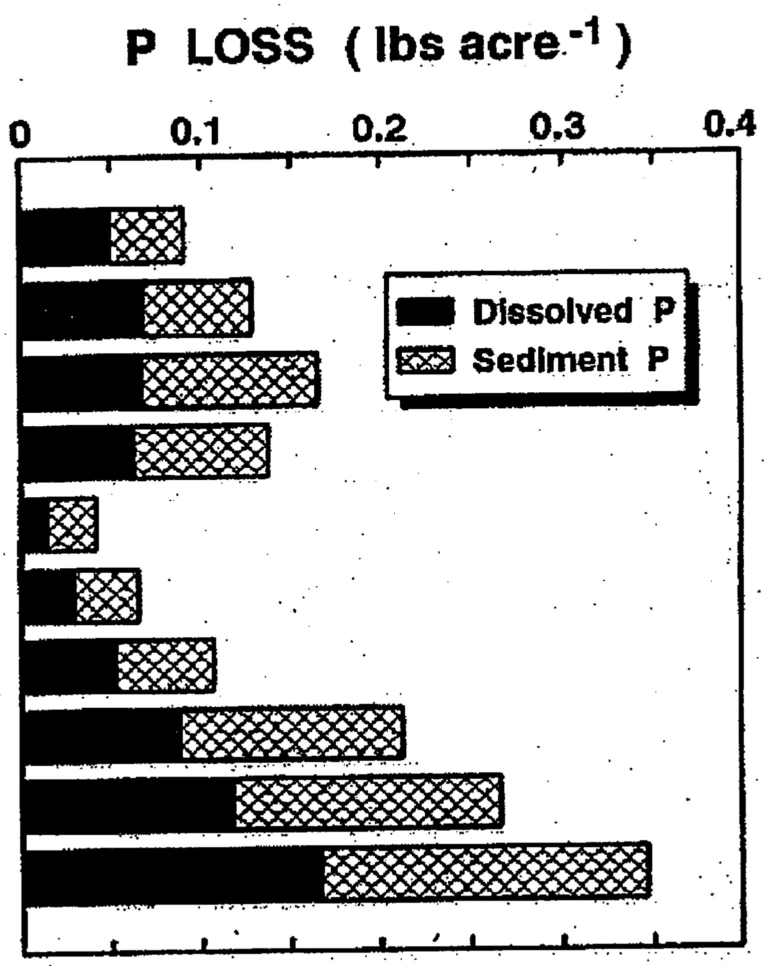

Figure 5. Phosphorus loss in runoff increases with land cultivation and disturbance.

Fertility Management

Crop yield response to soil test P is shown in Figure 6 which conceptualizes the process of making fertilizer P recommendations based on soil test P. Continual long-term application of fertilizer and manures at levels exceeding crop requirements, can raise soil test P above levels required for optimum crop yields in the runoff sensitive portion of surface soil (0 to 1 inch). Once soil test P levels become excessive, the potential for P loss, if runoff and erosion occur, is greater than any agronomic benefits of further P applications. After high levels of soil test P have been attained, several years are required for significant depletion.

In recent years, the number of soils with soil test P exceeding levels required for optimum crop yields, has increased in areas of intensive agricultural and livestock production. In 1989, several state soil test laboratories reported that the majority of soils analyzed had soil test P levels in the high or excessive categories (Fig. 7). These categories vary between states, with soil test P limits ranging from > 15 to > 110 lbs P $acre^{-1}$ for high and from > 25 to >250 lbs P $acre^{-1}$ for excessive.

Of particular concern, is the efficient utilization on locally limited land areas, of manure produced in confined animal operations. In many cases, manure applications have been N based, considering only soil N content and crop N requirements. This strategy can lead to an increase in soil test P levels, due to the generally lower ratio of N:P added in manure than taken up by crops. For example, poultry litter has an average N:P ratio of 3, while the N:P requirement of major grain and hay crops is 8.

The potential for surface soil accumulation of P is illustrated in Figure 8. If poultry litter is applied to meet crop N requirements, the amount of P added exceeds annual crop uptake of P.

A P driven strategy may mitigate the excessive build up of soil P and at the same time lower the risk for nitrate

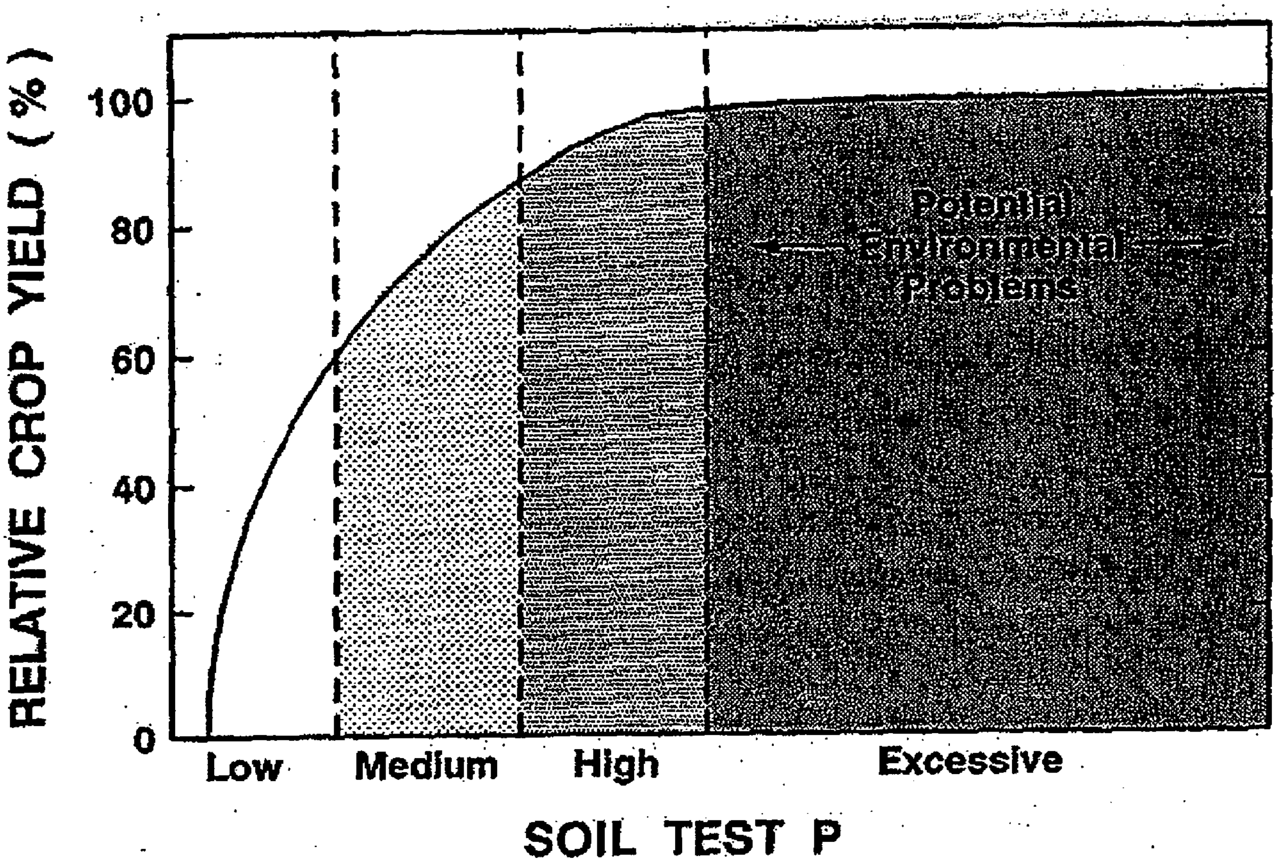

Figure 6. Relative crop yield increases with soil test P, but so does the potential for environmental problems.

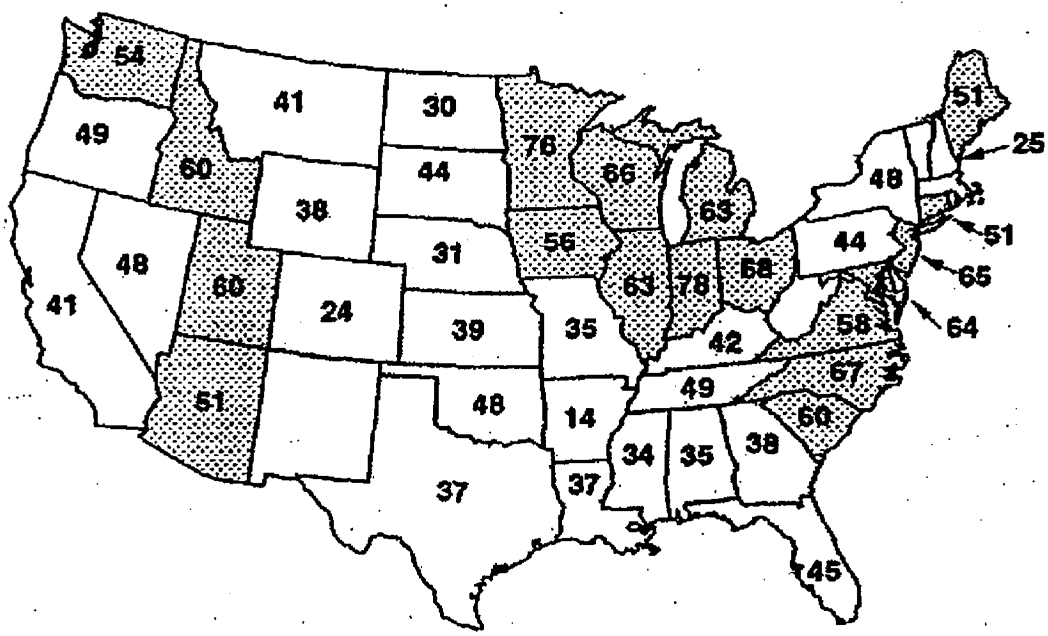

Figure 7. Percent of soil samples testing high or above for P in 1989. Highlighted states have 50% or greater of soil samples testing in the high or above range.

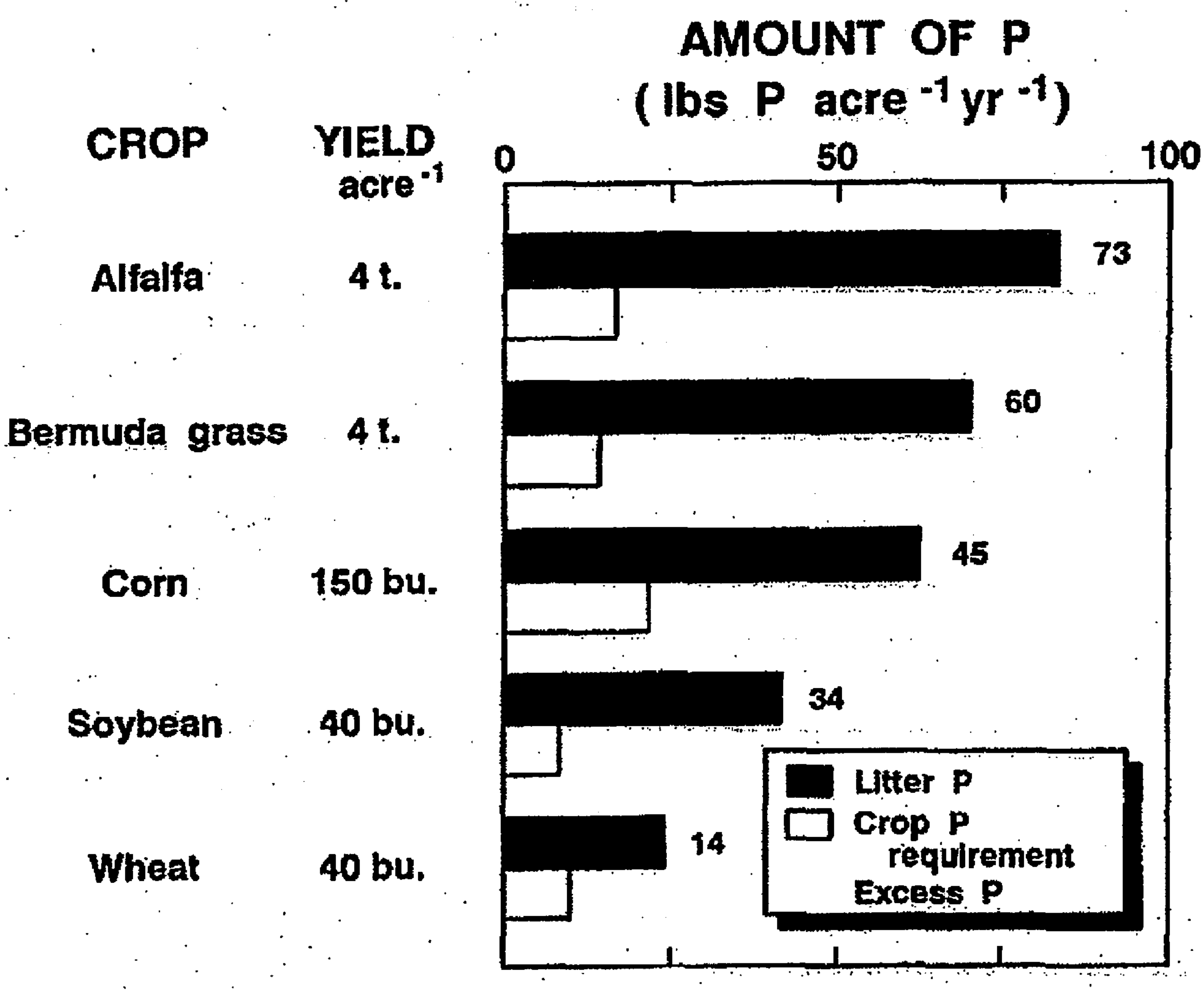

Figure 8. If rates of poultry litter application are based on crop N requirements, the amount of P added in litter exceeds crop P requirements.

leaching to ground water. However, basing manure applications on P rather than N management, could present several problems to many landowners. A soil test P-based strategy could eliminate much of the land area with a history of continual manure application, from further additions, as many years are required to lower soil test P levels once they become excessive. This would force landowners to identify larger areas of land to utilize the generated manure, further exacerbating the problem of local land area limitations.

Clearly, high soil test P levels are a regional problem, with the majority of soils in several states testing medium or low (Fig. 7). For example, most Great Plains soils still require fertilizer P for optimum crop yields. However, Figure 7 clearly illustrates that problems associated with high soil test P soils are aggravated by the fact that many of these soils are located near sensitive water bodies such as the Great Lakes, Chesapeake, and Delaware Bays.

Control Measures

Phosphorus loss from agricultural land can be reduced by erosion and runoff control and P source management. Erosion and runoff may be reduced by conservation tillage, buffer strips, riparian zones, terracing, contour tillage, cover crops, tile drainage, and impoundments or small reservoirs. However, these practices are more efficient at reducing particulate P than dissolved P losses. Under conservation tillage for example, the accumulation of crop residues and added P at the soil surface, provide a source of P to runoff that would be decreased during tillage. In addition, nitrate movement to ground water may increase under conservation compared to conventional tillage. Such water quality tradeoffs must be weighed against the potential benefits of conservation measures in assessing their effectiveness. Further, several studies have indicated little decrease in lake productivity with reduced P inputs following implementation of conservation measures. The lack of biological response is attributed to an increased bioavailability of P entering the lakes as well as internal recycling. Clearly, effective remedial strategies must address the management of P as well as erosion and runoff control.

Source control on soils susceptible to P loss involves fertilizer placement and the use of soil test P recommendations based on environmental rather than agronomic considerations to determine P application rates. Where possible subsurface placement of P away from the zone of removal in runoff will reduce the potential for P loss.

However, conflicts within Best Management Practices (BMP), between SCS residue management guidelines and recommended subsurface applications of P may exist. In compliance with residue conservation programs, landowners may be required to maintain a 30% residue ground cover. Under this BMP, subsurface application or knifing of P fertilizer or manure, may be recommended to minimize P loss in runoff, but could be unacceptable if it reduces residue cover. Thus, BMPs' should be flexible enough to for residue and P management plans to be compatible.

Assessing Site Vulnerability

Strategies to minimize P loss in runoff will be most effective if sensitive or vulnerable source areas within a watershed are identified, rather than implementation of general strategies over a broad area. Long-term field studies that reliably evaluate P movement are costly, lengthy, and labor intensive. Also, use of models simulating the effect of agricultural management on P loss in runoff often requires detailed soil information and computer experience to run them. Thus, a team of scientists led by SCS[1], developed an

[1]The team consists of J. Lemunyon, D. Goss, G. Gilbert, J. Kimble, T. Sobecki, USDA-SCS; A. Sharpley, USDA-ARS; T. Daniel, Univ. Arkansas; T. Logan, Ohio State Univ.; G. Pierzniyski, Kansas State Univ.; T. Sims, Univ. Delaware; and R. Stevens, Washington State Univ.

indexing system as a field tool to identify soils vulnerable to P loss in runoff.

Initial site assessment involves determining if runoff or leaching dominates water loss from a specific area (Table 1). If runoff is negligible and leaching potential is high, nitrogen should be used to guide fertilizer or manure applications. If from Table 1, surface runoff potential is medium or greater, then the P indexing system should be used.

The index is outlined in Tables 2 and 3. Each site characteristic affecting P loss is arbitrarily assigned a weighting, assuming that certain characteristics have a relatively greater effect on potential P loss than others. The P loss potential is given a value (Table 2), although each user must establish a range of values for different geographic areas. An assessment of site vulnerability to P loss in runoff is made by selecting the rating value for each site characteristic from the P index (Table 2). Each rating is multiplied by the appropriate weighting factor. Weighted values of all site characteristics are summed and site vulnerability obtained from Table 3.

Conclusions

There are many complex and interdependent factors affecting the fate and management of agricultural P in the environment. Thus, options available to landowners to remediate P-stimulated eutrophication of surface waters often require agronomic, economic, and/or environmental compromises. For example, conservation tillage may reduce total P loss in runoff but increase its' bioavailability and nitrate leaching. Also, linking manure applications may reduce soil test P levels but economically burden landowners having to transport manure greater distances and purchase N fertilizer to supplement crop N requirements.

Generally, the loss of agricultural P in runoff is not of economic importance to a farmer. However, it often leads to the deterioration of water quality from accelerated

Table 1. Runoff index to assess surface runoff potential.

CURVE NUMBER	ANNUAL PRECIPITATION (INCHES)				
	< 12	12 - 25	25 - 44	44 - 65	> 65
< 65	Low	Low	Low	Medium	High
65 - 75	Low	Low	Low	Medium	High
76 - 82	Low	Medium	Medium	High	Very high
> 83	Low	Medium	High	Very high	Very high

off-site concerns

ble 2. The phosphorus indexing system to rate the potential P loss runoff from site characteristics.

te Characteristic Veight)	Phosphorus Loss Potential (Value)				
	None (0)	Low (1)	Medium (2)	High (4)	Very High (8)
ansport Factors					
ɔil erosion .5)	Negligible	<10	10-20	20-30	>30
unoff Class 1.5)	Negligible	Very low or low	Medium	High	Very High
osphorus Source Factors					
ɔil P test .0)	Negligible	Low	Medium	High	Excessive
fertilizer oplication te (0.75)¶	None applied	1-15	16-45	46-75	>76
fertilizer oplication method .5)	None applied	Placed with planter deeper than 5 cm	Incorporated immediately before crop	Incorporated >3 months before crop or surface applied <3 months before crop	Surface applied >3 months before crop
ganic P source oplication rate .5)¶	None applied	1-15	16-30	30-45	>45
ganic P source oplication method :0)	None	Injected deeper than 5 cm	Incorporated immediately before crop	Incorporated >3 months before crop or surface applied <3 months before crop	Surface applied >3 months before crop

nits for soil erosion are Mg ha^{-1}

Inits for P application are kgP ha^{-1}.

Table 3. Site vulnerability to P loss as a function of total weighted rating values from the index matrix.

Site Vulnerability	Total Index Rating Value
Low	< 10
Medium	10 - 18
High	19 - 36
Very High	< 36

eutrophication, that can have significant off-site economic impacts. By the time these impacts are manifest, remedial strategies are often difficult and expensive for the landowner to implement; they cross political and regional boundaries; and it can be several years before an improvement in water quality occurs. Thus, identification of sources of P in runoff within a watershed or basin area is of prime importance in targeting cost-effective remedial strategies to minimize P loss. A P indexing system to rank soils as to their vulnerability for P enrichment of runoff may provide a field tool to fill this need.

Once a water body has been identified as being sensitive to P inputs, source fields and soils vulnerable to P loss in runoff must be carefully managed. Options include recommending that further P applications be made on an environmental rather than agronomic basis. For soils with a high or excessive soil test P level, options may involve applying no more P than removed annually by the crop. Fertilizer and manure applications based on environmental considerations to minimize potential P loss in runoff have been practiced in many parts of Europe since the mid-70's. After initial resistance to adoption of these guidelines, landowners are now widely understanding and receptive.

Judicious P amendments can reduce P enrichment of agricultural runoff via increased crop uptake and vegetative cover. Nevertheless, it is of vital importance that we implement management practices that minimize soil test P buildup in excess of crop requirements, utilize alternative P sources and residual soil P levels, and improve methods identifying soils capable of enriching bioavailable P loss in runoff to bring about a decrease in agricultural P loss to surface waters. Otherwise, the perception by the public that agriculture cannot manage itself for the good of the environment will increase. Unfortunately, the benefit of remedial measures on water quality improvement, will not be immediately visible to a concerned public. Consequently, future research and policy should emphasize the long-term economic and environmental benefits of these measures.

For further information contact Andrew Sharpley, USDA-ARS, National Agricultural Water Quality Laboratory, P.O. Box 1430, Durant, Oklahoma 74702-1430. Phone (405) 924 5066; FAX (405) 924 5307.

Andrew N. Sharpley

Dr. Sharpley is a Soil Scientist at the USDA-Agricultural Research Service, National Agricultural Water Quality Laboratory, Durant, Oklahoma and Adjunct Professor of Agronomy, Oklahoma State University. He received degrees from the University of North Wales, United Kingdom and Massey University, New Zealand. His research has focused on the cycling of phosphorus in soil-plant-water systems in relation to soil productivity and water quality and includes the management of fertilizers, crop residues and animal manures. He has developed formulations to improve model simulation of soil chemical processes and transport in runoff. He is a Fellow of the American Society of Agronomy and Soil Science of America, an Associate Editor of the Journal of Environmental Quality and Fertilizer Research, and past Chair of the Environmental Quality Division of the American Society of Agronomy.

ABSTRACTS FOR PRESENTATIONS ON ARKANSAS STUDIES INVOLVING PHOSPHORUS

SOIL FERTILITY PHOSPHORUS STATUS OF ARKANSAS SOILS

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ABSTRACT

Phosphorus (P) fertility status of Arkansas soils is measured by the Mehlich3 extractant. Among soil physiographic areas, loessial soils have low soil test P values, whereas the remaining areas have similar P distribution patterns (i.e. ~30% in the lowest category and 35% in the category that would not receive a fertilizer P recommendation for most crops). Among cropping systems, the rice-soybean complex contains soils with low P status, whereas cotton is grown on soils with high P status. The P status of soils for forage crops differs among forage species and as to whether the crop is to be established or maintained.

4-10# P_2O_5 fertilize must be put on to get 1# of soil test P increase

300#/ac P reading - no ~~xxx~~ more application recommended

ONRC 00610

IMMOBILIZATION OF PHOSPHORUS IN POULTRY LITTER WITH AL, CA, AND FE AMENDMENTS

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ABSTRACT

Arkansas produces approximately one billion broilers each year. Phosphorus (P) runoff from fields receiving poultry litter is believed to be one of the primary factors affecting water quality in Northwest Arkansas. Poultry litter contains approximately 10 g P kg^{-1}, of which about 2 g P kg^{-1} is water soluble. The objective of this study was to determine if P in poultry litter could be precipitated with Al, Ca, and/or Fe amendments. Poultry litter was amended with alum, sodium aluminate, quick lime, slaked lime, calcitic limestone, dolomitic limestone, gypsum, ferrous chloride, ferric chloride, ferrous sulfate and ferric sulfate and incubated in the dark at 25°C for one week. The Ca treatments were tested with and without CaF_2 additions in an attempt to precipitate fluorapatite. At the end of the incubation period, the litter was extracted with deionized water, and water soluble P was determined. Water soluble P levels in the poultry litter were reduced from over 2,000 mg p kg^{-1} litter to less than 1 mg P kg^{-1} litter with the addition of alum, quick lime, slaked lime, ferrous chloride, ferric chloride, ferrous sulfate and ferric sulfate under favorable pH conditions. Gypsum and sodium aluminate reduced water soluble P levels by 50 to 60 percent. Calcitic and dolomitic limestone were less effective. The results of this study suggest that treating litter prior to field application with some of these compounds could reduce the amount of soluble P in runoff from litter-amended pastures by orders of magnitude. Therefore, chemical additions to reduce soluble P in litter may be a best management practice in situations where eutrophication of adjacent water bodies due to P runoff has been identified. Preliminary calculations indicate that this practice should be economically feasible with at least two of these compounds. However, more research is needed to determine any beneficial and/or detrimental aspects of this practice.

TRANSPORT OF PHOSPHORUS FROM LAND AREAS TREATED WITH ANIMAL MANURES

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ABSTRACT

This report summarizes two years' plot-scale research into phosphorus transport dynamics. Animal manures (poultry litter, poultry manure, swine manure) and inorganic fertilizer were applied to small (1.5 x 6 m) plots covered with "tall" fescue. The plots are located at the Main Agricultural Experiment Station in Fayetteville, Arkansas, and the soil at the research site is a Captina silt loam. Rainfall simulators were used to produce runoff from the plots. Various experiments were conducted to define the influences of phosphorus source, phosphorus application rate, rainfall intensity, drying interval between phosphorus application and simulated rainfall, and multiple storms on runoff concentrations of both total and dissolved reactive phosphorus. Flow-weight composite samples were analyzed for all plots, and individual samples collected during runoff were analyzed for selected treatment replications. Flow-weighted mean runoff phosphorus concentrations were similar between animal manures and were lower for animal manure phosphorus sources than for the inorganic phosphorus source for the first post-application runoff event. Runoff phosphorus concentrations increased in direct proportion to phosphorus loading rate and decreased with increasing simulated rainfall intensity for the first post-application runoff event. Drying intervals of from 1 to 14 days between application and first runoff event did not influence runoff phosphorus concentrations for plots treated with swine manure and poultry litter. Runoff concentrations of phosphorus decreased rapidly with successive storms for plots treated with poultry litter and inorganic fertilizer, approaching background levels after three simulated storms. Analyses of individual samples collected during runoff indicated that runoff concentrations of both total and dissolved reactive phosphorus are generally inversely proportional to runoff rate.

SPATIAL RELATIONSHIPS BETWEEN PHOSPHORUS AND AQUEOUS PHOSPHORUS CONCENTRATIONS IN THE WAR EAGLE WATERSHED

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ABSTRACT

In recent years there had been increased concern about the surface water quality in Northwest Arkansas. The general public opinion seems to be that wastes from agricultural practices such as poultry and swine operations are primarily responsible for most of any reduction in water quality. The assumption is that excessive quantities of nutrients from these mostly organic fertilizers are reaching surface waters; thus, increasing aqueous nutrient concentrations to high levels. Of the three major fertilizer elements, phosphorus (P) seems to be the growth limiting factor for many aquatic microbiological populations. Research in large reservoirs has shown that there is a direct relationship between algal populations and P concentrations. Therefore, the focus upon the fate of P in the environment has resulted in numerous models that predict the form and movement of P across the landscape. One such model is the Phosphorus Index (PI). This model was designed to assess influencing landforms and management practices for potential risks of P movement to water bodies. The model identifies sites where risks of movement may be relatively higher than at other sites. The required input parameters of the PI model can be obtained from a geographic information systems (GIS) database allowing the spatial characteristics of the database to be incorporated into the PI model. This study used a GIS with the PI model along with available soil P concentrations in the War Eagle watershed. Spatial attributes of soils, geology, and land use/land cover were digitized. The plant- available P concentrations in the various soils of the watershed were obtained from the county extension office. The land use/land cover database allowed a ranking of pasture quality and the location of pastures with evidence of fertilization. The GIS software GRASS was used to compute PI values for the watershed and to predict movement of P across the watershed. The P movement across the landscape was related to the aqueous P concentrations in the water samples taken along War Eagle Creek by personnel of the Department of Pollution Control and Ecology.

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PHOSPHORUS DYNAMICS IN STREAMS AND RESERVOIRS OF THE WESTERN OZARK PLATEAU

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ABSTRACT

The western edge of the ozark plateau ecoregion contains free-flowing streams and streams impounded by reservoir. The Buffalo National River represents the free-flowing stream and serves as the ecoregion reference stream. Many of the streams are impounded for drinking water resources and/or recreation. The longitudinal and seasonal dynamics of soluble reactive phosphorus-P (SRP-P) is described for representative streams and impoundments. The role of periphyton and phytoplankton is discussed. Also, the importance of SRP-P in limiting algal community growth is addressed.

MINIMIZING LAKE AND RESERVOIR EUTROPHICATION BY PHOSPHORUS MANAGEMENT

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ABSTRACT

Phosphorus (P) is identified as the nutrient which limits excessive production of aquatic weeds and algae in lakes and reservoirs. Therefore, nutrient management programs should focus on this nutrient to minimize eutrophication from agricultural nonpoint-source pollution in targeted water bodies. Phosphorous chemistry is reviewed with an aim toward putting important runoff P parameters in proper perspective. Important sources are presented and special attention is given to runoff P from animal waste and soils with elevated P levels. A systematic procedure for constructing a cost-effective management program designed to limit eutrophication from agricultural nonpoint pollution is presented. Included are procedures to: 1) select P-sensitive lakes/reservoirs, 2) identify target areas or "hot spots" in the watershed where land implementation of best management practices should be focused, and 3) identify specific fields to be treated using a P-indexing approach. A discussion of Best Management Practices (BMPs) that focus on limiting runoff P is presented.

BIOGRAPHICAL SKETCHES OF SPEAKERS

TOMMY C. DANIEL

Dr. Daniel is a Professor of Agronomy at the University of Arkansas in Fayetteville, Arkansas. He holds a B.S. in Agronomy from Texas A&M University, a M.S. in Horticulture and a Ph.D. in Soils-Water Chemistry from the University of Wisconsin in Madison, Wisconsin. Dr. Daniel's areas of specialization are water quality, nonpoint pollution, contaminant transport, runoff, and leaching. Before coming to the University of Arkansas, he was a professor of Soil Science at the University of Wisconsin. Professor Daniel's most recent publications include Comparison of PRZM simulate and measured pesticide mobility under two tillage systems and Microlysimeter soil column for evaluating pesticide movement through the root zone.

DWAYNE R. EDWARDS

Dr. Edwards is currently Assistant Professor in the Biological and Agricultural Engineering Department at the University of Arkansas in Fayetteville. A new course, Modeling of Water Quality Processes, has been developed and approval has been secured by Dr. Edwards. He earned his B.S. and M.S. in Agricultural Engineering at the University of Arkansas in 1984 and 1986 respectively and a Ph.D. in Agricultural Engineering at Oklahoma State University in 1988. Research interests include water quality, hydrologic modeling, water management and conservation, and nonpoint pollution. Dr. Edwards has secured significant external support to develop a research program in the water quality area with emphasis on impacts of animal waste on surface water and has recruited graduate students to build a research program capable of addressing major environmental issues related to agricultural production. He is the leader of an externally funded project to develop information on effects of control practice implementation on water quality in areas treated with animal wastes and a co-leader of an externally funded project which has led to the acquisition of benchmark data on water quality effects of land-applied animal waste. Dr. Edwards is a member of the American Society of Agricultural Engineers, American Society of Engineering Education, American Water Resources Association, Alpha Epsilon, Gamma Sigma Delta and other professional and honorary societies. Dr. Edwards has received the Region IV U.S. Environmental Protection Agency Environmental Excellence Award in 1992, Halliburton Award for Outstanding Research in 1992, and Honorable Mention, Transactions of the ASAE 1989 Paper Awards.

RICHARD L. MEYER

Dr. Meyer is currently a Professor at the University of Arkansas in the Department of Botany and Microbiology and Associate Director of the Arkansas Water Resources Center. He received his B.S. degree in Biology and Education at Missouri Valley College, Marshall, Missouri in 1954 and a Ph.D. in Botany and Zoology at the University of Minnesota in 1965. Research activities in the Phycology Laboratory includes taxonomy, systematics, phylogeny and developmental morphology of desmids and chrysophycean algae. Additional research involves studies on the ecology of phytoplankton populations in large and small reservoirs. Research on the periphytic algae in streams stresses variations in geological substrates, nutrient conditions, determination of thermal regimes and the influence of flow on subcommunity structure. Dr. Meyer is a member of the American Water Resources Association, Arkansas Section of American Water Resources Assoc., American Association for the Advancement of Science, Sigma Xi and various other professional organizations.

PHILIP MOORE

Dr. Moore received a B.S. in Soil Science and M.S. in Agronomy from the University of Arkansas. He received a Ph.D. in Marine Sciences from LSU. His major professor at LSU was Bill Patrick, the director of the Wetland Biogeochemistry Institute. While at LSU, Moore received both a Fulbright and a Rockefeller Scholarship. He then studied the geochemistry of phosphorus in lakes at the University of Florida as a Post-doc. In 1990, he went to work for the University of Arkansas at the Southeast Research and Extension Center in Monticello where his research focused on water quality problems associated with rice production. Last August, he began working for USDA/ARS in Fayetteville where he is investigating methods of improving the agricultural utilization of poultry litter, while decreasing any negative environmental impacts of this resource.

WAYNE E. SABBE

Dr. Sabbe received B.S. at North Dakota State University and Ph.D. at Oklahoma State University. He worked for the USDA-ARS as a Cotton Physiologist at University of Arkansas from 1963-1966. Since 1966 he has been at the University of Arkansas with the Department of Agronomy as an Assistant Professor from 1966-1970, Associate Professor from 1970-1975, and Professor from 1975 to the present time. Currently he has responsibility for the overall Soil Testing Program. Dr Sabbe was born, raised and educated in North Dakota.

H. DON SCOTT

Dr. Scott is currently a Professor of Soil Physics in the Department of Agronomy, Associate Director of the Arkansas Water Resources Center, and Associate Director of the Center for Advanced Spatial Technologies. He received his B.S. in Crop Science at N. C. State University in 1966, a M.S. in Soil Science at N. C. State University in 1968, and a Ph.D. from the University of Kentucky in 1971. Dr. Scott conducts research in soil and water management. These research studies have centered around the effects of drought and properly scheduled irrigation on the growth, development and yield of soybeans grown in the mid South, transport of water and solutes in soils, the spatial and temporal variability of soil properties in the landscape, and the use of geographic information systems for water quality analysis. He has published over 110 publications. In addition, he and his students have made 76 presentations on their research at regional and national scientific meetings. Dr. Scott has developed courses in Soil Physics, Advanced Soil Physics, Mathematical Modeling for the Life Sciences and Honors Colloquium in Agriculture. He has twice been invited to serve as a member of the national water quality research review panel for USDA, a review panelist for the competitive grants in the U.S. western region on fate and transport of solutes, and was a member of the review panel for one year and was topic manager for USDA-Small Business Incentive Research grants in the soil-air-water section. Dr. Scott is a member of the American Society of Agronomy, Soil Science Society of America, CAST, Sigma Xi, and Gamma Sigma Delta.

BIOGRAPHICAL SKETCHES OF PANEL MEMBERS

ALLEN CARTER

Allen Carter began work for the Arkansas Game and Fish Commission in 1972 as fisheries biologist in training. He had hatchery duties for six months, creel clerk and assistant district fisheries biologist for approximately two years, district fisheries biologist for six years, fisheries regional supervisor for three and a half years, and fisheries assistant chief for three years. Allen's current position is the Fisheries Chief for the Arkansas Game and Fish Commission that he has held for five and a half years. He received a B.S. degree in Wildlife Management from Arkansas Tech University in 1972 and an M.S. degree in Biology from Arkansas State University in 1984. Allen is an Arkansas native.

JOHN GIESE

John Giese is Chief of the Environmental Preservation Division of the Arkansas Department of Pollution Control and Ecology. He began working for the department in 1968 as a technician in the wet chemistry laboratory. In 1971, he was promoted to an ecologist position in the Water Division. While serving as an ecologist, he conducted numerous investigations of pollution problems, developed experience in investigative procedures involved in sampling of aquatic life, collection of water samples, bacteriological sampling, toxicological studies, and report preparation. In 1990, he was selected to fill the Chief's position in the newly developed Environmental Preservation Division. Current areas of responsibility involve review and revision of environmental regulations, technical writing, data assessment, and program development. He received a B.S. in Biology at the Arkansas Technical University in 1967 and an M.S. in Science from the University of Arkansas, Fayetteville in 1972.

TOM MCKINNEY

Tom McKinney is the Administrative Director for the Northwest Arkansas Environmental Guardianship, a group that seeks to build working relationships between the business sector and environmental organizations to address local and regional environmental problems. He has been active with the Sierra Club in Arkansas for almost twenty years. Tom has been the Chair of his local group in north Arkansas, the Ozark Headwaters Group, as well as the Chapter Chair of the Arkansas Sierra Club. He is currently serving as the Chapter Conservation Chair responsible for coordinating the conservation activities of the 2,000 Sierra Club members in Arkansas. Currently, these efforts include working to address non-point source water pollution problems, an ongoing effort to reform the U.S. Forest Service into a multiple use organization rather than its current status of industrial tree farmers, and efforts to protect Arkansan's free flowing streams. Tom is a native son of Arkansas currently living in West Fork in northwest Arkansas.

RONNIE MURPHY

Ronnie Murphy was selected as state Conservationist for Arkansas in 1991 and currently holds that position. He has served as soil-conservationist, economist, area conservationist, and assistant state conservationist in various locations in Alabama, Illinois, and Nebraska. He has served as legislative assistant in Washington, D.C. and Deputy State Conservationist in Arkansas. Ronnie was detail to the Lower Mississippi Delta Development Commission to assist in the development of its plan to improve the economic conditions in the Delta region. He earned a B.S. and M.S. degree in Agricultural Economics from Auburn University and a Master of Public Administration from Harvard. Born in Florence, Alabama, Ronnie was raised on the family farm.

ANDREW N. SHARPLEY

Dr. Sharpley is a Soil Scientist at the USDA-Agricultural Research Service, National Agricultural Water Quality Laboratory, Durant, Oklahoma and Adjunct Professor of Agronomy, Oklahoma State University. He received degrees from the University of North Wales, United Kingdom and Massey University, New Zealand. His research has focused on the cycling of phosphorus in soil-plant-water systems in relation to soil productivity and water quality and includes the management of fertilizers, crop residues and animal manures. He has developed formulations to improve model simulation of soil chemical processes and transport in runoff. He is a Fellow of the American Society of Agronomy and Soil Science of America, an Associate Editor of the Journal of Environmental Quality and Fertilizer Research, and past Chair of the Environmental Quality Division of the American Society of Agronomy.

EARL SMITH

Earl Smith graduated from the University of Arkansas, Fayetteville, in 1973 with a M.S. in Environmental Engineering. In 1985 he accepted the position of Chief, Water Resources Management Division of the Arkansas Soil and Water Conservation Commission. Earl has served in an advisory capacity to the Governor's Animal Waste Task Force and has supervisory oversight of personnel in fulfilling the Commission's responsibility as the state's lead agency in nonpoint source pollution management. He has provided key staff support in the development and adoption of Rules and Regulations for Utilization of Surface Water, Rules for Utilization of Ground Water, and Rules for Water Development Project compliance with the Arkansas Water Plan. Leadership and supervisory oversight has been provided by Earl in the establishment of minimum streamflows on the Arkansas River. He is a member and Past President, Arkansas Section, of the American Society of Civil Engineers and a member of the National Society of Professional Engineers.